

Percutaneous Multiple Kirschner Wire Fixation in the Treatment of Hand Fractures

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Purpose: We reported results of percutaneous multiple K-wire fixation technique without passing through the joint in patients with a hand fracture.

Methods: We evaluated a total of 116 cases in 94 patients who underwent percutaneous multiple K-wire fixation on dorsal cortex over a 10-year period between 2001 and 2010. The treatment outcomes were evaluated based on total active motion (TAM), as proposed by Widegrow.

Results: Our clinical series of patients achieved good functional outcomes. Of total patients, 89% (84/94) had excellent TAM, 2% (2/94) did good TAM and 9% (8/94) did poor TAM. Postoperatively, our clinical series of patients had such a good compliance as to achieve a TAM of >181° when performing the early active movement. There were no notable postoperative complications during the follow-up period.

Conclusion: Our results indicate that percutaneous multiple K-wire fixation technique without passing through the joint from normal bone density patients is effective in providing the rigid fixation. Thus, our patients could perform the early movement as promptly as possible and maintaining the full mobility of the rest of the hand.

Keywords: Hand, Fractures, bone, Fracture fixation, Bone wires, Motion

INTRODUCTION

The hand fracture is one of the most common traumas, and it accounts for up to 10% of all the human body fractures^{1,2}. Its etiologic factors include sports activities, traffic accidents and industrial work activities. There is a variability in the management of hand fracture. This poses challenging problems for surgeons. The treatment goal is to obtain good outcomes, for which surgeons should consider 1) restoration of

the normal alignment, 2) achievement of the appropriate union, 3) recovery of the early range of movement and earlier return to full activities, and 4) absence of residual disabilities or deformities

It is difficult to maintain reduction without causing undesirable side effects. The complications of hand fracture include infection, non-union, malunion, tendon adhesion and joint stiffness³. Of these, the most serious potential problem is an inability to attain a full range of movement. There

are multiple factors which limit the range of motion, and these include structural problems such as concurrent injuries to the joint or tendon, i.e., the overlying structures that perform a gliding function, and soft tissue injuries including neurovascular injuries. Moreover, the limited range of motion is correlated with infection, swelling, pain and non-rigid, unstable fixation⁴. All of these factors cause tendon adhesion or joint stiffness by maintaining the immobilized hand.

For the effective treatment of hand fracture, the early active motion as well as the rigid fixation should be achieved. In addition, the postoperative complications should be prevented and the normal functions of the hand based on the maximum range of motion should be restored⁵.

We performed the percutaneous multiple K-wire technique on dorsal cortex without passing through the joint in patients with hand fracture and obtained good treatment outcomes. Here, we present our surgical methods and their outcomes based on our 10-year single institution experience.

MATERIALS AND METHODS

1. Patients

A total of 94 patients (116 cases) underwent percutaneous multiple K-wire fixation over a 10-year period between 2001 and 2010. We performed a retrospective analysis of such variables as location, direction of the fracture line, amount of displacement, degree of malalignment, angulation, subluxation, dislocation, rotational deformity (malrotation), presence or absence of comminution and articular involvement. Inclusion/exclusion criteria for the current study are as follows: 1) Inclusion criteria, patients with phalangeal or metacarpal fractures of the hand with normal bone density. 2) Exclusion criteria, patients with low bone density; patients with concurrent carpal fractures; patients with fractures with large bone defects; patients with fractures associated with replantation; patients with severely mutilated injuries requiring primary amputation; patients who required skin grafting.

We finally enrolled a total of 94 patients (116 cases) in the current study. The current study was approved by the Institutional Review Board of our medical institution.

Because of its retrospective nature, the requirement for obtaining a written informed consent was waived.

2. Surgical techniques

The basic principle of the surgical treatment for hand fractures is to realign the mobile segment to the less mobile one. Under local anesthesia, axillary block anesthesia in some cases, with or without standard C-arm fluoroscopic guidance, the fractures were properly treated with closed or open reduction when there was a concurrent presence of injury. Reduction of the fracture was done by pulling or traction of the finger with an even distribution of the sufficient pressure. After the fractures were well aligned and good reduction was obtained by closed or open manipulation, multiple K-wires were placed using a power driver percutaneously starting from the dorsal cortex to the other side dorsal cortex above the mid-lateral line for maximizing rigidity. In metacarpal fractures, multiple K-wires were percutaneously inserted in a transverse direction and then horizontally placed in the stable unit of the hand. The non-fractured adjacent bone was served as the stable unit that is expected to play a role as the cornerstone of the bridge (Fig. 1). In comminuted fractures, we passed multiple K-wires through the largest segment into the smaller one and then fixed to each other, thus attempting to increase the rigidity, and thereby stabilized the fracture without passing K-wires through the joint (Figs. 2, 3). Then, we encouraged the patients to perform the early movement.

We applied the sufficient compression by manual forces or encouraged the patients to move the hand for daily activities. Thus, we attempted to evaluate whether the range of motion and the stability of fixation are so sufficient as to maintain the reduction (Figs. 3, 4). Unless the fixation had been sufficient or bone fractures had been immobilized, we would have performed the longitudinal percutaneous K-wire fixation. But there were no such cases. The pins were withdrawn within a mean period of four weeks postoperatively (range, 3–6 weeks).

3. Postoperative management

After the internal fixation, we initiated the early mobilization without delay while maintaining the adequate alignment of the fragments with rigid fixation. When there were no con-

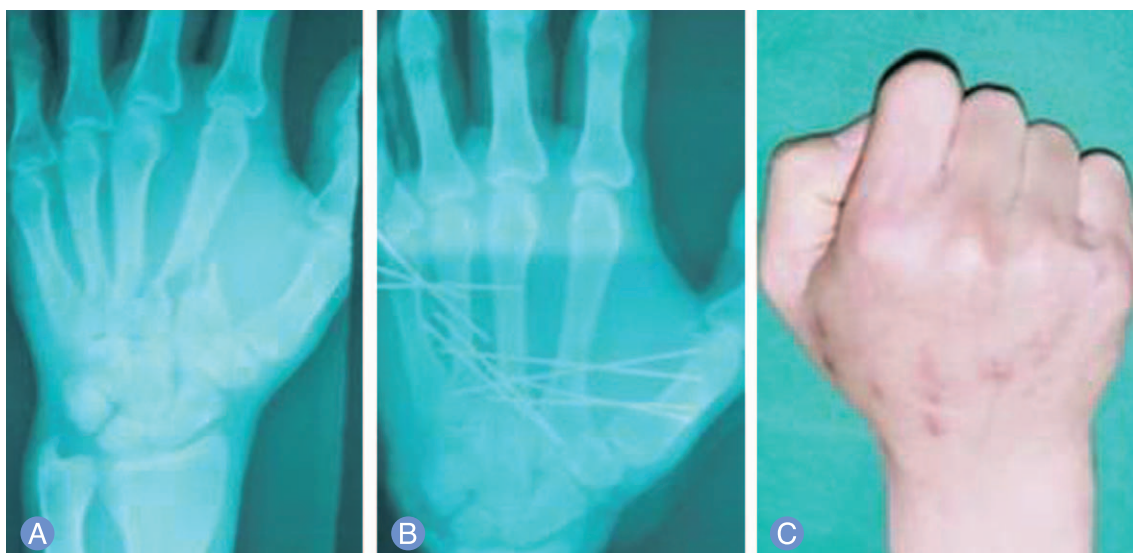


Fig. 1. Spiral metacarpal fracture with rotational malalignment. (A) Spiral fractures with rotational deformity of the index metacarpal shaft and long metacarpal base. (B) Closed reduction and internal fixation of each spiral fracture with percutaneous multiple K-wires stabilized the fracture yet allow movement. The third and fourth metacarpal function as a foundation stone. No wire was transfixed through the metacarpophalangeal joint surface. (C) On postoperative year 1, no rotational malalignment was observed and patient restored alignment with a full range of motion.



Fig. 2. Rigid fixation of comminuted diaphyseal fracture. (A) Diaphyseal fracture of the index proximal phalanx with comminution. (B) Immediately after surgery, with the fixation by percutaneous multiple K-wires without passing through the joint, the rigid fixation was maintained during the active flexion.

current injuries in such body areas as the tendon, collateral ligament and neurovascular structures, the patients were allowed to perform early mobilization within 7 to 14 days postoperatively. We encouraged the patients to perform active motion. In addition, we also added the passive range of

motion when there was a limitation in the movement because of swelling or pain. Postoperatively, there were no patients who needed splint protection because there was a sufficient stability due to a rigid fixation with multiple K-wires although the patients with concurrent tendon injuries were

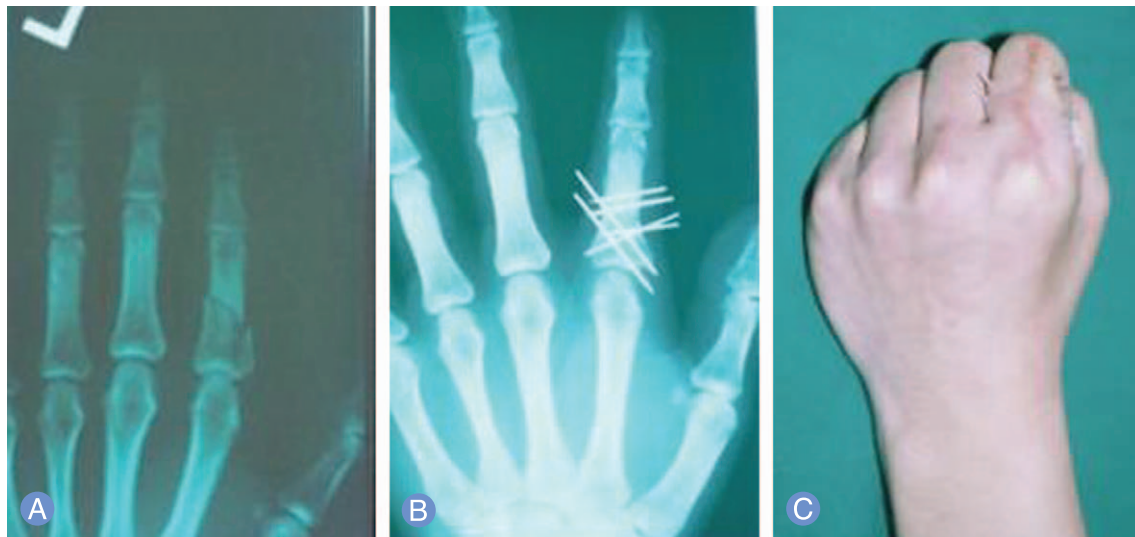


Fig. 3. Early mobilization after percutaneous multiple K-wire fixation. **(A)** Proximal phalangeal shaft, base fracture with comminution of the index finger. **(B)** Closed reduction and percutaneous multiple K-wires. **(C)** With the rigid fixation without passing through the joint, the early active movement was promoted. The degree of motion was satisfactory on post-operative day 3.

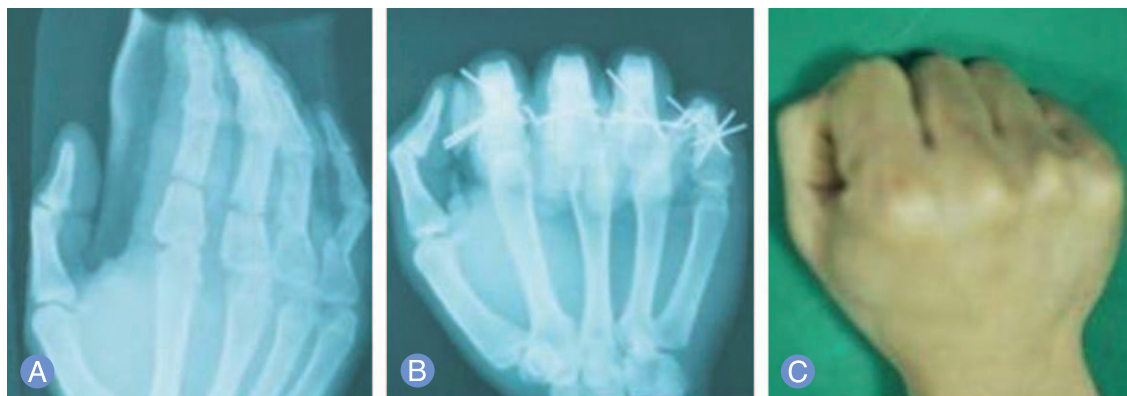


Fig. 4. Multiple transverse fractures with concurrent injuries. **(A)** Multiple transverse fractures of the shaft with the tendon injuries in the proximal phalanges accompanied by the dorsal, concave angulation. **(B)** Immediately after surgery, the rigid fixation and the early active motion were achieved using the percutaneous multiple K-wire technique. **(C)** On postoperative year 1, the full range of motion was restored and there were no residual disabilities or deformities.

in need of dynamic splinting. In patients who had injuries to neurovascular structures, however, the early mobilization was permitted after 14 days postoperatively.

4. Evaluation of outcomes

The treatment outcomes are based on such variables as the range of joint motion, the degree of deformity, grasping function, pain and sensory recovery. In an actual clinical setting, however, it is difficult to objectively evaluate all the above variables. Moreover, there was a variability in the period of

long-term follow-up. We therefore evaluated the total active movement (TAM), as proposed by Widgerow (Table 1). The TAM refers to an additive sum of three movements: the flexion at the metacarpophalangeal, the proximal interphalangeal, and the distal interphalangeal joints minus the extension deficit at the same joints⁶. Thus, we classified the treatment outcomes based on the TAM into three grades: 'excellent (TAM >250°)', 'good (181° < TAM < 249°)', and 'poor (TAM < 180°)'.

RESULTS

1. Characteristics of the patients

The mean age of the patients was 53-year-old (range, 23–82 year-old), and they consisted of 54 men and 40 women. The most common fracture was metacarpal fracture, accounting for 48% (56/116) of total cases (Table 2). Our clinical series of patients include six cases of intra-articular fracture, 18 cases of spiral fracture and 12 cases of comminuted fracture.

2. Clinical outcomes

As shown in Table 1, our clinical series of patients achieved good functional outcomes. Of total patients, 89% (84/94) had excellent TAM, 2% (2/94) did good TAM and 9% (8/94) did poor TAM. Postoperatively, our clinical series of patients had such a good compliance as to achieve a TAM of $>181^\circ$ when performing the early active movement. All of our clinical series of patients were followed up postoperatively, and underwent uneventful course and achieved a recovery of hand motion. Furthermore, there were no patients who had malunion or nonunion of the fracture as well as residual deformities (Figs. 1, 4).

DISCUSSION

The hand is one the most essential organs of the human

Table 1. Functional outcomes based on the total active movement

Outcomes	TAM	No. of patients (%)
Excellent	$>249^\circ$	84 (89)
Good	$181^\circ\sim 249^\circ$	2 (2)
Poor	$<180^\circ$	8 (9)

The total active motion (TAM) refers to an additive sum of three movements: the flexion at the metacarpophalangeal, the proximal interphalangeal and the distal interphalangeal joints minus the extension deficit at the same joints.

Table 2. Fracture site and accompanying injuries

Fracture site	No concurrent injuries	Tendon injuries	Neurovascular structure injuries	Total no. of cases
Distal phalanx	2	0	0	2
Middle phalanx	4	4	2	10 (S: 2, C: 2)
Proximal phalanx	32	10	6	48 (I: 6, S: 2, C: 6)
Metacarpal	38	12	6	56 (S: 14, C: 4)

I, intra-articular fracture; S, spiral fracture; C, comminuted fracture.

body, and it is characterized by the sophisticated functions and complicated architecture. In addition, it is vulnerable to trauma with the industrial development and the increased use of transportation. The hand fracture accounts for 30% of all industrial fractures, and it is the most frequently seen⁷.

The management of hand fracture is a Cinderella subject; it is subject to the extent and mechanism of injury, patient's age, concurrent injuries and surgeons' technical expertise. To put this in another way, there is no established treatment modality for hand fracture. The optimal treatment modality should be chosen on a case-by-case basis. According to Swanson, patients with hand fracture may be complicated; it may lead to the deformity when left untreated, stiffness when overtreated and both deformity and stiffness when incorrectly treated⁸. This suggests that it would be mandatory to select the optimal treatment modality for each case although many cases of hand fracture can be treated by conservative management at the present⁹. In an actual clinical setting, there are some patients who achieve a recovery even when almost or completely left untreated. If overtreated or incorrectly treated, however, patients will present with deformity or other severe complications than the deformity. According to Curry¹⁰, the basic principle of the surgical treatment for hand fractures is to realign the mobile distal segment to the less mobile proximal one.

Active measures can be taken if a satisfactory reduction cannot be achieved or if there are concurrent injuries in such areas the vessels, nerves, tendons or other soft tissues. Surgical treatments of hand fracture can be classified into the internal fixation and the external one. In the internal fixation, the reduction is achieved by percutaneous K-wire pinning, interosseous wiring and the fixation with a plate and a screw. Percutaneous K-wire pinning is a common surgical technique that is both simple and cost-effective. In addition, it is advantageous in that it can be versatile used for skeletal stabi-

lization and it causes less complications¹¹. Black et al.¹² analyzed the rigidity of three methods, 1) the dorsal plating with or without lag screws, 2) the intraosseous wiring, and 3) the K-wire pinning, for the treatment of metacarpal fracture. This showed that the dorsal plate fixation and the wired techniques provided the most and the least rigid fixation, respectively. With the most stable fixation, patients can initiate the early active movement as promptly as possible. Despite the stable fixation, the plate system reveals several disadvantages due to a plate and a screw. That is, the plate is somewhat huge and then cannot be easily used for the fixation of hand phalanges. In addition, it needs an wide exposure for the extensive periosteal stripping. With the inappropriate location of the plate, the normal gliding of the tendon would be compromised¹³. Moreover, it would be mandatory to remove both a screw and a plate at the second operation. To date, however, no attempts have been made to stabilize the rigidity of K-wire fixation because it has the great advantages. By contrast, the K-wire fixation minimally needs the periosteal elevation, but it is also known to provide the unstable fixation that limits the early active movement in patients with hand fracture¹².

Rush and Rush¹⁴ attempted the use of immediate intramedullary wiring in the treatment of patients with metacarpal fracture. But these authors did not use splints but recommended that patients perform the early movement of the hand and finger.

To date, many authors have emphasized the importance of the early mobilization in patients with hand fracture. In association with this, Dobyns et al.¹⁵ reported that final treatment outcomes would be improved if at least a partial arc of motion is restored as promptly as possible. The treatment outcomes would vary depending on the type of treatment methods and the duration of immobilization. It is well known that the small joints of the hand are prone to stiffen with immobilization. In the rehabilitation program, the early active mobilization based on the flexion and extension of the hand and finger should be considered of primary concern and it can be attained when patients maintain the rigid fixation of reduction. Other digits and joints of the extremities should be mobilized as promptly as possible. Thus, attempts can be made to prevent the sympathetic dystrophy as well as total

loss of hand function⁸. Our clinical series of patients had no immobilized joints and they were permitted to perform the early mobilization.

According to Clifford¹⁶, the treatment goal of hand fracture is to reduce the fractures and to immobilize them. But we assume that the treatment goal of hand fracture is to reduce the fractures with stable fixation and to provide patients with the early active movement without immobilization.

We treated patients with hand fracture simply with percutaneous multiple K-wire fixation without passing through the joint and thereby obtained such satisfactory outcomes that it achieved a sufficiently rigid fixation in the reduced position without joint immobilization. Then, we could shorten the usual postoperative course by subsequently performing the early active movement. In our series, the early movement including both the active and passive motion was effective in minimizing the occurrence of soft tissue swelling, achieving a recovery of the gliding function of tendon around the joints, thus preventing the occurrence of posttraumatic tendon adhesions, and allowing unrestricted motion of the joint, thus preventing the occurrence of joint stiffness and enabling patients to return to the daily lives. After achieving a rigid fixation, patients appeared to recover joint stability and could initiate the early mobilization without delay.

Our surgical methods were also effective in correcting rotational deformities in patients with spiral fracture or comminuted one because the percutaneous multiple K-wire fixation provided such a sufficient stability as to maintain the reduction. In particular, the percutaneous multiple K-wire fixation technique is appropriate for patients with metacarpal fracture. Therefore, our clinical series of patients achieved an adequate fixation even when they had a concurrent presence of rotational malalignment. Unlike the plate and screw system, the percutaneous multiple K-wire fixation is a cost-effective procedure that it does not need a second operation. Moreover, there is no need to pass the K-wire through the joint. Furthermore, the periosteal elevation for the direct visualization of the fracture is needed only at a minimal level in patients who are indicated in open reduction.

Our results cannot be applied to patients with vascular diseases, those with low bone density and pediatric ones who had epiphyseal growth plate. In addition, surgeons cannot

use the K-wire fixation in patients with hemodynamic derangement¹³.

With the percutaneous insertion of multiple K-wires into the soft tissues, the range of early mobilization can be limited because of the restricted tendon gliding or intrinsic muscle movement. In our series, however, the above findings promptly disappeared immediately after the removal of pins. In addition, there were also a small number of patients where the final range of active movement was left intact. These patients restored the functions of the hand.

To summarize, for the past ten years, we have used the percutaneous multiple K-wire fixation technique in 94 patients with hand fracture and thereby obtained satisfactory treatment outcomes. Our clinical series of patients showed no postoperative complications and a good prognosis. Our surgical technique is straightforward and fairly simple but the effect of surgeon experience is required for overcoming the learning curve.

CONCLUSION

In conclusion, our results indicate that the percutaneous multiple K-wire fixation technique without passing through the joint is effective in providing the rigid fixation. Thus, our patients could perform the early movement as promptly as possible and maintaining the full mobility of the rest of the hand.

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다발성 K-강선을 이용한 수부 골절의 치료

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목적: 정상 골밀도 소견을 보이는 환자군의 수부 골절 치료에 있어 다발성 K-강선을 이용하여 관절면의 통과 없이 고정된 결과를 보고하고자 한다.

대상 및 방법: 2001년부터 2010년까지 94명 116예의 수부골절 환자들을 대상으로 다발성 K-강선을 이용하여 배측 피질골에 고정을 시행하였으며 Widegrow가 제한한 총능동운동(total active motion, TAM)으로 수술 후 결과를 측정, 평가하였다.

결과: 대부분의 환자에서 만족할 만한 결과를 보였다. 89% (84/94)에서 TAM $\geq 250^\circ$ 를 보였으며 2% (2/94)에서 $181^\circ < \text{TAM} < 250^\circ$, 그리고 9% (8/94)에서 TAM $< 180^\circ$ 의 결과를 보였다. 견고한 고정 후 조기운동을 실시한 환자군에서 TAM $> 181^\circ$ 의 좋은 결과를 얻었다. 추적기간 동안 합병증은 발생하지 않았다.

결론: 정상 골밀도 소견을 보이는 환자의 수부 골절 치료에 있어 다발성 K-강선을 이용하여 관절면의 관통없이 골절편을 견고하게 고정한다면 조기에 능동 및 수동운동을 시행할 수 있으며 이것은 수부의 빠른 기능 회복에 도움을 줄 것으로 생각된다.

색인단어: 수부, 골절, 골절고정, 금속강선, 운동

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